Handout 1 – Descriptive Chemistry 1

Apr 3, 2019

- Doing chemistry requires both understanding ideas and remembering key information

[Pre-Reading & Pre-assignments]:

(Zumdahl9e) Chp20/21; (Atkins7e) Focus8/9 (*Optional*)

Worksheet - Flinn AP Chem Chemistry Reaction (Google Classroom)

Q5 or Q6 - Reaction Writing in National 2014-2018 Part II/Q7-12 (Part I)

[Learning Objectives]:

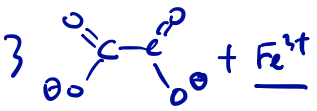
- Metal reactivity and extraction of metals
- Reactions of representative metals
- Pourbaix diagram and typical redox titrations
- Prediction of unknown reactions based on reactions types

1. Classification of Redox Reactions

Introductory Question: Why do we need to summarize the reactions types?

Subtypes	Examples (net ionic equation if in aqueous)
Combustion (O_2/air)	$Li(s) + O_2(g) \rightarrow Li_2O$ $Na(s) + O_2(g) \xrightarrow{\Delta} Na_2O_2$ heating NaO_2 superoxide $S(s) + O_2(g) \rightarrow SO_2$ (SO_2X) KO_3 (O_3^-) $P(s) + O_2(g) \rightarrow P_4O_{10}$ (P_2O_5)
Combustion (other oxidants)	$Mg(s) + N_2(g) \rightarrow Mg_3N_2$ / MgO $Mg(s) + CO_2(g) \rightarrow MgO + C$ $Fe(s) + Cl_2(g) \rightarrow FeCl_3$ $FeCl_2$ X $^*Fe(s) + S(s) \rightarrow FeS$
Single-displace (metals)	$Fe(s) + H^+(aq) \rightarrow Fe^{2+} + H_2(g)$ pre-H metals $Cu(s) + H^+(aq) \rightarrow X$ post-H metals $Cu(s) + Ag^+(aq) \rightarrow Cu^{2+} + Ag$
Single-displace (nonmentals)	$Cl_2(g) + Br^-(aq) \rightarrow Br_2 + Cl^-$ $BrCl$ X $F_2(g) + H_2O(l) \rightarrow O_2 + HF$
Typical redox titrations	$H^+ +$ (acidified) $MnO_4^-(aq) + C_2O_4^{2-}(aq) \rightarrow CO_2 + Mn^{2+} + H_2O$ (+7, +3, +4, +2) (acidified) $MnO_4^-(aq) + H_2O_2(aq) \rightarrow Mn^{2+} + O_2$ (-1, 0)

Note



lab handout – empirical formula

https://bit.ly/2FXvP8S

https://bit.ly/2YQmUxF

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

O	F
S	Cl

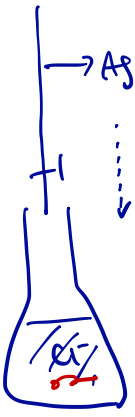
nonmetallic

https://bit.ly/2uGAntS

https://bit.ly/2YJDLC2

https://bit.ly/2uJOMFK (6:35)

https://bit.ly/2Ibllo3 (N2018-Q8)



CrO_4^{2-} Ag^+ → $Ag_2CrO_4(s)$ ✓ AB

AgCl(s) + white

AB

$S(AgCl) < S(Ag_2CrO_4)$ ✓

MO : 3.1 - 4.4 ✗

MR : 4.4 - 6.2 ✓

NH_4Cl

$pH = \sqrt{0.1 \times 10^{-5}} = 10^{-3}$

$K_b(NH_3) = 10^{-5}$

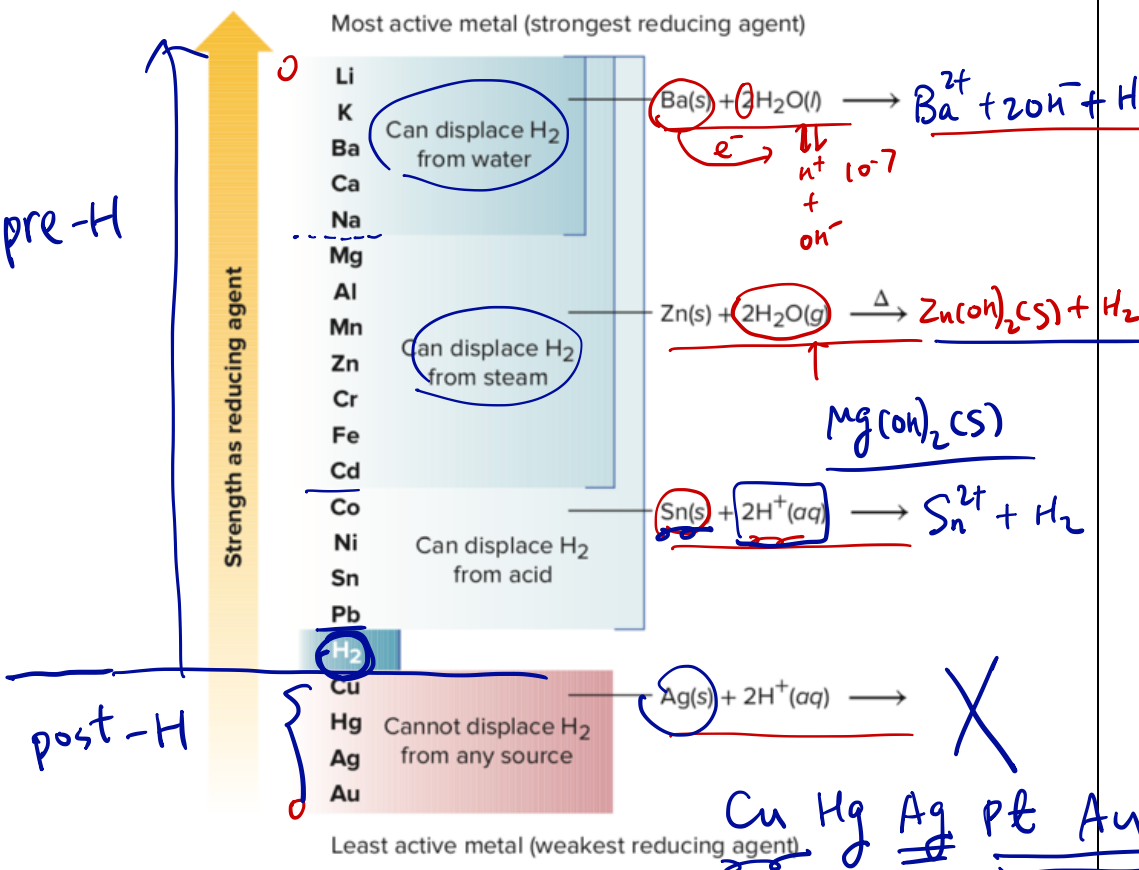
$K_a(NH_4^+) = \frac{K_w}{K_b}$

$= 10^{-9}$

10^{-9} 10^{-5}

$pH = 5$

2. Redox Reactions and Standard Reduction Potential



pre-H

post-H

Mg(OH)2(s)

Kw(25°C) = 10⁻¹⁴

Kw(100°C) > 10⁻¹³

Cu Hg Ag Pt Au inert electrodes

Extended Questions:

(a) Why only pre-Hydrogen metals can replace hydrogen gas from water or acid?

$E^\circ_{M^{n+}/M} < 0 = E^\circ_{H^+/H_2}$ $E^\circ_{cat} > E^\circ_{ano}$ $E^\circ_{cell} > 0$, $\Delta G^\circ < 0$, spon-

(b) When small amount of Zn(s) is added to a solution of 0.1 M $Cu(NO_3)_2$(aq) and 0.1 M $AgNO_3$(aq), what is the reaction?

Ag^+ ✓ $E^\circ_{Ag^+/Ag} > E^\circ_{Cu^{2+}/Cu}$

(c) Without looking into the above series, how do you think of the reactivity of Li/Na/K/Rb/Cs, Na/Mg/Al and Cu/Ag/Au? What are the experimental evidences, respectively?

stronger → weaker ??? → weaker

https://bit.ly/1MGnFdZ

periodicity

$E^\circ(Fe^{2+}/Fe) = -0.44$ V

$E^\circ(Fe^{3+}/Fe^{2+}) = +0.77$ V

$E^\circ_{Fe^{3+}/Fe} = ?$ 0 V

$\Delta G^\circ = -nFE^\circ$

(d) What is the product of Fe(s) reacting with H^+(aq), Fe^{2+}(aq) or Fe^{3+}(aq)? Justify your answer by referring to the standard reduction potentials.

Fe^{2+} ✓

(e) How does the reactivity affect the extraction of metals from their ores? What are the typical metals made by electrolysis?

https://bit.ly/2uKMsyk (N2016-Q39)

(f) Na is used to extract K from KCl(l) under relative high temperature, which is the process to synthesize K in industry. Write down the equation with the state of each substance marked and analyze the driving force of the reaction?

Na(l) + KCl(l) $\xrightarrow{T}$ NaCl(l) + K(g) ↑ S

(g) Can post-Hydrogen metals like Cu and Au react with acids? How and why?

aqua regia (HNO3/HCl)

Li
Na
K
Rb
Cs
bp decreasing

3. Metals Reacting with Acids

Metals	Strong acids [HCl(aq), H_2SO_4 (**dilute**)]	Oxidizing acids **No H_2 produced!** Why?
Pre-H metals	H_2	H_2SO_4 (**conc.**) → SO_2 (toxic, beach fuchsine) HNO_3 (**conc.**) → NO_2 (reddish brown) HNO_3 (**dilute**) → NO (colorless)
Post-H metals (Cu-Hg-Ag-Pt-Au)	**No reaction**	

$E^{\circ}_{NO_3^-/NO} > E^{\circ}_{H^+/H_2}$ ($[H^+]=1M$)

$E^{red}_{M^{n+}/M} > 0$ $E^{\circ}_{H^+/H_2}$ positive

https://bit.ly/2UbukN0 (Cu + conc. H_2SO_4)

https://bit.ly/2FHcKq0 (penny + conc. HNO_3)

https://bit.ly/2ONa9Pr (L2011-Q3)

https://bit.ly/2FWVePU (L2012-Q7)

Extended Question: What are the reactions of oxidizing acids such as conc. H_2SO_4 with nonmetals such as carbon and sulfur?

$C + H_2SO_4(conc.) \xrightarrow{heat} CO_2 + SO_2 + H_2O$

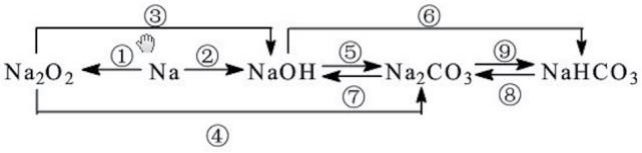
$S + H_2SO_4(conc.) \xrightarrow{heat} SO_2 + SO_2 + H_2O$

4. Representative Metals – Na, Al, Fe

Introductory Question: Why these three, what is the character of each one?

Na – Representative of reactive metals

Write down the (net ionic if applicable) equation of each reaction



https://bit.ly/2HXWPYi (Na_2O_2)

① $Na + O_2 \xrightarrow{combustion} Na_2O_2$

② $Na + H_2O \rightarrow Na^+ + OH^- + H_2$

③ $Na_2O_2 + H_2O \rightarrow Na^+ + OH^- + O_2$

④ $Na_2O_2 + CO_2 \rightarrow Na_2CO_3 + O_2$

⑤ $OH^-_{(ex)} + CO_2 \rightarrow CO_3^{2-}$ ✓

⑥ $OH^- + CO_{2(ex)} \rightarrow HCO_3^-$ ✓

* ⑦ $CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3(s)$

⑧ $2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2 + H_2O$

⑨ $CO_3^{2-} + CO_2 + H_2O \rightarrow 2HCO_3^-$

H_2O_2 → X

$HO_2^- + Na^+$

double displacement

$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$

Na^+ O_2^{2-} H^+ OH^-

$H_2O + O_2$

$O_2^{2-} \rightarrow O^{2-} + O_2$

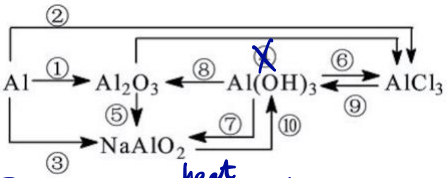
Limewater

$Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3(s) + 2NaOH$

Al – Representative of amphoteric metals

Write down the (net ionic if applicable) equation of each reaction

$AlO_2^- = Al(OH)_4^- =$ *aluminate*



$Al(H_2O)_6^{3+} \equiv Al^{3+}$

① $Al + O_2 \xrightarrow{heat} Al_2O_3$

② $Al + Cl_2 \xrightarrow{combustion} AlCl_3$

③ $Al + OH^- + H_2O \rightarrow Al(OH)_4^- + H_2$

⑥ $Al(OH)_3 + H^+ \rightarrow Al^{3+} + H_2O$

⑤ $Al_2O_3 + OH^- \rightarrow Al(OH)_4^- + H_2O$

⑦ $Al(OH)_3 + OH^- \rightarrow Al(OH)_4^-$

⑧ $Al(OH)_3 \xrightarrow{heat} Al_2O_3 + H_2O$

⑨ $Al^{3+}_{(ex)} + OH^- \rightarrow Al(OH)_3(s)$

or $Al^{3+} + NH_3 + H_2O \rightarrow Al(OH)_3(s) + NH_4^+$

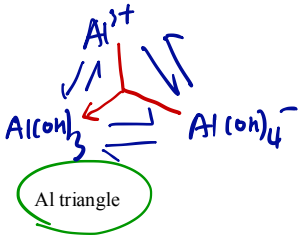
④ $O^{2-} + H^+ \rightarrow H_2O$

$Al_2O_3 + H^+ \rightarrow Al^{3+} + H_2O$

⑩ $Al(OH)_4^-{}_{(ex)} + H^+ \rightarrow Al(OH)_3(s) + H_2O$

or $Al(OH)_4^- + CO_2 + H_2O \rightarrow Al(OH)_3(s) + HCO_3^-$

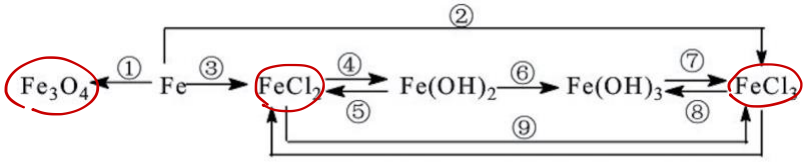
$M(OH)_n(s) \xrightarrow{\Delta} M_2O_n + H_2O$



https://bit.ly/2VpEjet (Al + NaOH)

Fe – Representative of transition metals with multiple oxidation numbers

Write down the (net ionic if applicable) equation of each reaction



① $Fe + O_2 \xrightarrow{combustion} Fe_3O_4\ (FeO \cdot Fe_2O_3)$

② $Fe + Cl_2 \xrightarrow{combustion} FeCl_3$

③ $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$

④ $Fe^{2+} + OH^- \rightarrow Fe(OH)_2(s)$

⑤ $Fe(OH)_2 + H^+ \rightarrow Fe^{2+} + H_2O$

⑥ $Fe(OH)_2 + O_2 + H_2O \rightarrow Fe(OH)_3(s)$ ✓ reddish brown

⑦ $Fe(OH)_3 + H^+ \rightarrow Fe^{3+} + H_2O$ white → green

⑩ ⑧ $Fe^{3+} + OH^- \rightarrow Fe(OH)_3$

⑨ $Fe^{2+} + Cl_2 \rightarrow Fe^{3+} + Cl^-$

⑩ $Fe^{3+} + Fe \rightarrow Fe^{2+}$

https://bit.ly/2WDGB9M (Fe_3O_4)

https://bit.ly/2OOPSta ($Fe(OH)_2$)

https://bit.ly/2K4I5sm (OH^- + Fe^{2+}/Fe^{3+})

https://bit.ly/2CTgdS0 (N2017-Q7)